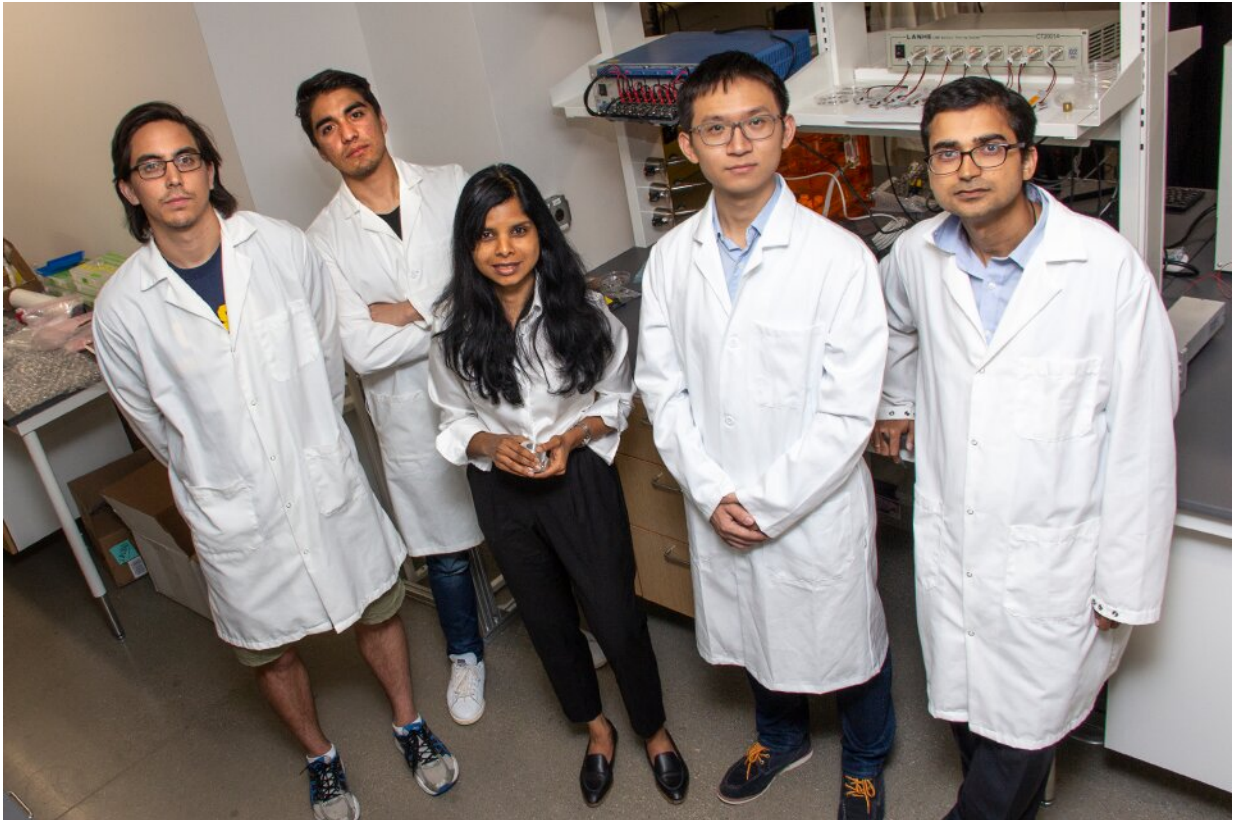


A path to the future, paved with ceramics

March 15 2019, by Anne Boyle



Reeja Jayan and her research team investigate how electromagnetic fields speed up ceramic fabrication, finding both challenges and great potential. Credit: College of Engineering, Carnegie Mellon University

When you hear the word "ceramics," you may think of the mug you made in pottery class or the vases collecting dust on your grandmother's shelf. While these objects are made up of ceramics, they're only one

small part of the bigger picture. Ceramics are being used in armor, lasers, electronics, teeth replacement, and more. They ensure that your computer's motherboard runs smoothly. They protect space shuttles when most other materials would burn up in the atmosphere. In other words, ceramics are everywhere, and they're essential.

They also come with a price. Processing of many ceramics requires heating them up to temperatures over 2,000 degrees centigrade for several hours. That's a significant spending in energy. At Carnegie Mellon University, B. Reeja Jayan is working to solve this problem with her unconventional source of power.

Jayan is an assistant professor in mechanical engineering and directs CMU's Far-from-Equilibrium Materials Laboratory. She is investigating the use of electromagnetic fields in ceramics fabrication, specifically with regards to sintering and synthesis. Sintering is the process in which a porous material, such as clay, densifies under pressure or with heat. She detailed the new developments in this field of research in the January 2019 cover article of the *Journal of the American Ceramic Society*.

The paper traces its origins back to a two-day workshop held at Carnegie Mellon in June 2017, titled Electromagnetic Effects in Materials Synthesis. The workshop gathered scientists working in three different areas of field-assisted material synthesis. "This workshop was a good opportunity to learn from each other," her postdoctoral researcher, Shikhar Jha, comments. "These methods—microwave, laser, and [electric field](#)—are very different from each other, but we hope to figure out a common theme to relate them to a single mechanism."

At the workshop, the scientists grappled with the question of why electromagnetic fields speed up sintering. "We want to see if these field-driven processes for sintering and synthesis are all thermally driven, or if

the field itself is inducing additional driving force," Jayan says. In other words, is the field just providing extra heat, or is it doing something else entirely?

This question presents unique research opportunities. In addition to making the process more efficient, researchers can also process new materials with new properties. "We're not expecting the behavior and the properties of [materials](#) to be identical to what they were," Jayan says. "We have found them to be different, but we don't know how, and therein lies opportunities."

However, there are several obstacles preventing their full understanding of the process, including the available tools of characterization. "You cannot use a thermocouple to measure it," Jayan says, "because the [field](#) will also interact with the thermocouple and give you unreliable data."

Another issue is the dynamic nature of the process. "If you only measure the material properties and microstructure afterward, you don't know what happened in the intermediate phase," Jayan says. Due to this, studies that measure processes as they are happening, called in situ studies, have become invaluable. Jayan's group is working with National Laboratories to use a synchrotron source, a type of electron accelerator, to shed light on the intermediate steps of structural changes during such processes.

The final issue is one of scale. When studying sintering, "you need to be able to connect and stitch together all the length scales," Jayan says, "from atoms all the way up to large parts you can hold in your hands." In order for scientists to understand the underlying mechanisms, they need to develop characterization and modeling techniques that can determine the evolution of structures over time at different scales.

While the challenges may seem daunting, the result would be worth the

effort. If scientists understood the role of external fields in the sintering process, they could accelerate technological development in a wide array of fields, including manufacturing, pharmaceuticals, electronics, and clean energy. Already, their efforts are yielding results. The 20-hour time frame "is coming down to seconds," Jayan says, "and the temperature is coming down to a few hundred degrees. This is a significant saving in energy."

Jayan and her team hope that their paper will serve as a call to action for a new generation of students and researchers. More than anything, it "was about bringing a knowledge gap to the community," Jayan says, "and telling them: here's an opportunity. Let's work together."

More information: The effects of external fields in ceramic sintering, *Journal of the American Ceramic Society*, doi.org/10.1111/jace.16061

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